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FORCE TESTS ON A SEPARABLE-NOSE CREW ESCAPE CAPSULE IN PROXIMITY TO THE PARENT FUSELAGE AT MACH NUMBERS 1.5 THROUGH 4.5

Jerry H. Jones

ARO, Inc.

August 1966

VON KÁRMÁN GAS DYNAMICS FACILITY

ARNOLD ENGINEERING DEVELOPMENT CENTER

AIR FORCE SYSTEMS COMMAND

ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

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Jerry H. Jones

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FOREWORD

The work reported herein was done at the request of the Air Force Flight Dynamics Laboratory (AFFDL), Air Force Systems Command (AFSC), under Program Element 62405364, Project 1362, Task 136203.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF 40(600)-1200. The tests were conducted from May 2 to May 10, 1966, under ARO Project No. VA0508. The manuscript was submitted for publication on June 29, 1966.

This technical report has been reviewed and is approved.

Donald E. Beitsch
Major, USAF
AF Representative, VKF
Directorate of Test

Leonard T. Glaser
Colonel, USAF
Director of Test

ABSTRACT

Static force tests were conducted in the 40-in. supersonic tunnel of the von Kármán Gas Dynamics Facility on a separable-nose crew escape capsule in the presence of the forward section of the airplane fuselage. The separation rocket jet plume was simulated with cold air. Data were obtained at Mach numbers from 1.5 through 4.5 at capsule angles of attack from -14 to 20 deg. The fuselage section, relative to the capsule, was positioned at several locations aft of the capsule at zero angle of attack. Reynolds number, based on a model length of 18.1 in., ranged from 1.81×10^6 to 9.41×10^6. Selected results are presented showing the effects of the fuselage section on the static longitudinal stability and drag characteristics of the capsule.

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ILLUSTRATIONS

TABLE

NOMENCLATURE

A	Reference area (cross-sectional area at separation bulkhead), 22.608 in.^{2}
C_D	Drag coefficient, drag/$q_\infty A$
C_L	Lift coefficient, lift/$q_\infty A$
C_m	Pitching-moment coefficient, pitching moment/$q_\infty A \ell$
ℓ	Reference length (distance from nose to separation bulkhead), 16.5 in.
M_∞	Free-stream Mach number
p_c	Jet chamber pressure, psia
p_o	Tunnel stilling chamber pressure, psia
p_∞	Free-stream static pressure, psia
q_∞	Free-stream dynamic pressure, psia
Re	Reynolds number
T_o	Tunnel stilling chamber temperature, °R
α	Angle of attack, deg

SECTION I
INTRODUCTION

These tests constitute a part of Phase II of a wind tunnel test program requested by the Flight Recovery Group (FDFR), AFFDL, to provide data for investigating crew escape systems for high-speed flight vehicles. In Phase I (Ref. 1) the static stability and drag characteristics of the F-104 aircraft separable-nose escape capsule were obtained for angles of attack from -30 to 30 deg with cold flow simulation of the exhaust plume from the escape rocket at various altitudes. In these Phase II tests, static longitudinal stability and drag data were obtained on the capsule in proximity to the forward section of the airplane fuselage. The fuselage section position relative to the capsule varied from 3.09 to 13.38 in. aft of the capsule and from 3.34 to 11.78 in. below the capsule.

During later Phase II tests of this program, a remotely controlled support system will be used to position the fuselage with respect to the capsule and provide independent pitch and yaw of both capsule and fuselage. Other crew escape capsule configurations will also be tested.

Static force data were obtained at Mach numbers from 1.5 through 4.5 at capsule angles of attack from -14 to 20 deg. The fuselage angle of attack was zero. Reynolds number, based on a model length of 18.1 in., ranged from 1.81×10^6 to 9.41×10^6.

SECTION II
APPARATUS

2.1 WIND TUNNEL

The 40-in. supersonic tunnel (Gas Dynamic Wind Tunnel, Supersonic (A)) is a continuous, closed-circuit, variable density wind tunnel with an automatically driven, flexible-plate-type nozzle and a 40- by 40-in. test section. The tunnel operates at Mach numbers from 1.5 to 6 at maximum stagnation pressures from 29 to 200 psia, respectively, and stagnation temperatures up to 760°R (M_∞ = 6). Minimum operating pressures are about one-tenth of the maximum at each Mach number. Further tunnel information may be obtained in Ref. 2.

2.2 MODELS

The separable-nose escape capsule model and the fuselage section model (Figs. 1 through 3) were 1/10-scale models of the F-104 aircraft and were provided by AFFDL. The capsule had three wedge-shaped stabilizing booms extending to the rear. These booms (Fig. 1c) were positioned 120 deg apart, and the upper boom was fitted with a trim tab (Figs. 1a and b). The cold air jet nozzle was positioned in a cutout on the lower aft portion of the model (Fig. 1e) and was attached to the sting such that the model was isolated from the jet reaction force.

Details of the nozzle are given in Fig. 1d, and the procedures used to calculate the nozzle dimensions and chamber pressures for simulation of the full-scale jet plume shape at various altitudes over the Mach number range are given in Ref. 1.

The fuselage section model (Fig. 1f) was strut mounted from the tunnel sidewall. Three strut lengths were used to obtain the fuselage positions shown in Fig. 2. As shown in this figure, configurations 2 and 2a were identical except that a section at the top of the fuselage was removed for configuration 2a, Fig. 1f. The purpose of this was to allow clearance for the capsule sting support at angles of attack ($\alpha > 4$ deg). The three longitudinal slots in the fuselage simulate the storage locations of the capsule stabilizer booms while the aircraft is in normal flight. The cutout on the bottom of the fuselage is a relief for the escape rocket exhaust during initial firing.

2.3 INSTRUMENTATION

Capsule force measurements were made with a six-component, moment-type, strain-gage balance supplied and calibrated by the von Kármán Gas Dynamics Facility. Prior to the test, loadings in a single plane and combined static loadings were applied to the balance which simulated the range of model loadings anticipated for the test. The range of uncertainties listed below corresponds to the differences between the applied loads and the values calculated with the balance equations used in the final data reduction. The minimum uncertainties given are for loads up to about 10 percent of the maximum applied and are for loadings on the particular component only (no combined loading interaction effects). The maximum uncertainties are for combined loadings.

Balance Component	Design Load	Range of Static Loadings	Range of Uncertainties
Normal Force, lb	250	±20 to ±250	±0.40 to ±0.75
Pitching Moment, in.-lb	1234	0 to ±350	±4.70
Axial Force, lb	300	50 to 300	±0.25 to ±1.25

Two jet chamber pressure measurements were made using transducers calibrated for a full-scale range of 1000 psia and considered accurate to within 1 percent of full scale.

Base pressures were measured with transducers calibrated for full-scale ranges of 15-, 5-, and 1-psid, referenced to a near vacuum, and considered accurate to within 0.25 percent of full scale. A base drag correction was made for the balance cavity area only.

A summary of the test conditions is given in Table I.

SECTION III
RESULTS AND DISCUSSION

The effects of the presence of the fuselage section on the static longitudinal stability and drag characteristics of the escape capsule, jet off and jet on, are presented in Figs. 4 through 9 for Mach numbers 1.5, 2.5, 3.5, and 4.5. Configuration 1 in these figures is the capsule alone, and the results are from the phase I tests (Ref. 1). Configuration 7 was not tested at Mach 1.5 since the capsule bow shock would reflect from the tunnel wall between the capsule and fuselage, and the configuration 7 data at Mach 4.5 are not presented since the tunnel boundary layer separated upstream of the fuselage and influenced the flow about the capsule.

It can be seen that the effects of removing the section of fuselage to allow sting clearance for configuration 2a (Fig. 1f) generally resulted in a shift in the magnitude of the coefficients between configurations 2 and 2a, the trends of the data remaining the same (see Fig. 4a for an example). The data for configurations 2 and 2a also show some very large discontinuities with jet on, particularly at negative angles of attack (Figs. 5b, c, and d). These discontinuities are a result of changing local flow conditions on the trailing boom, and in the high-pressure region at the capsule base, as the angle of attack changes. At the negative angles of attack, the jet impinges on the front portion of the fuselage section and causes large regions of flow separation over the capsule. Schlieren photographs of configuration 2 at $M_\infty = 3.5$ for angles of attack of 0, -6, and -8 deg and

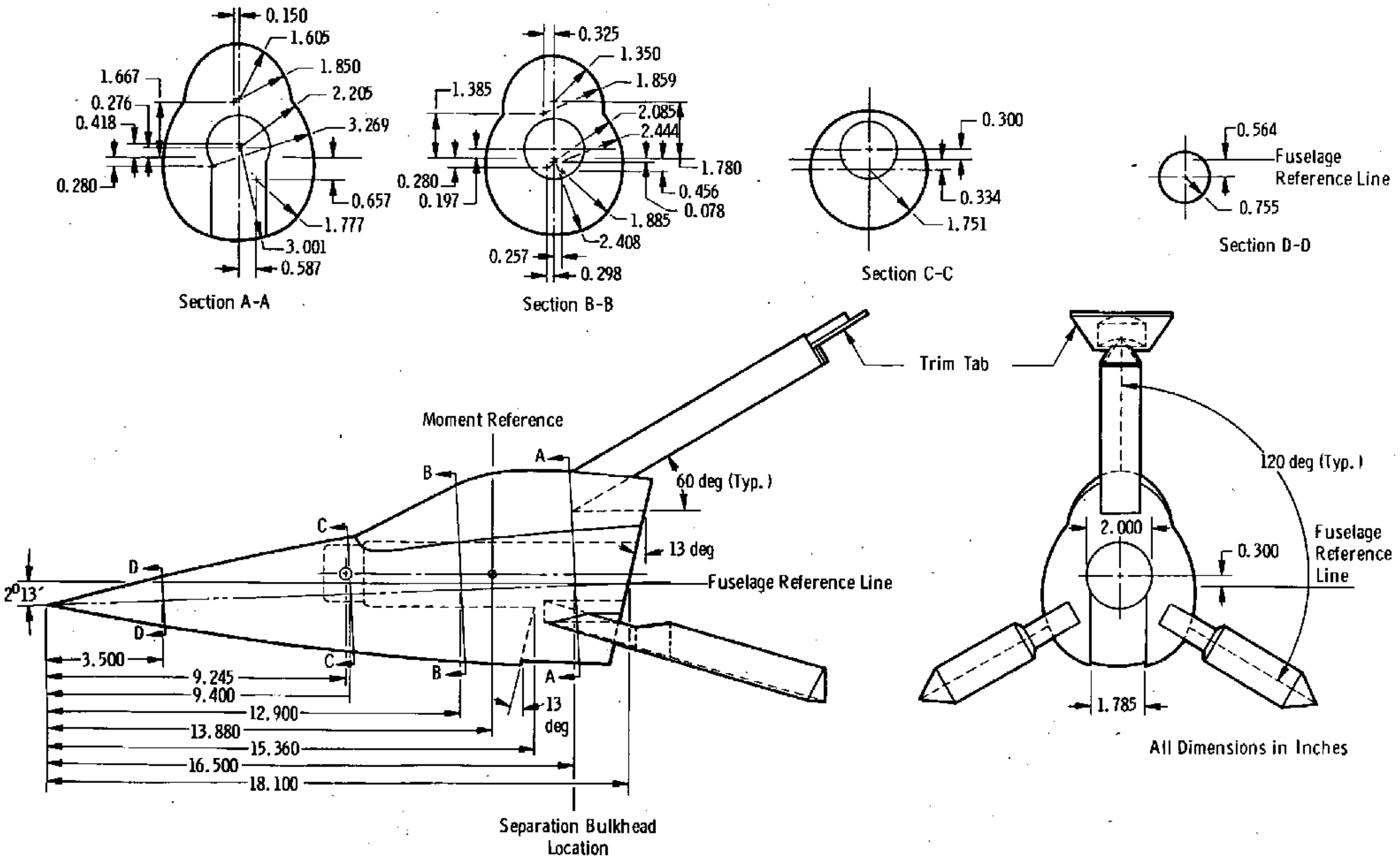
p_c/p_∞ = 4204 are given in Fig. 6. As can be seen, the flow is separated up to the nose of the capsule at α = -8 deg.

Some of the data presented in Figs. 4 and 5 for Mach numbers 1.5, 2.5, 3.5, and 4.5 are summarized in Figs. 7, 8, and 9 for the jet off and jet on to show the effect of the fuselage position on the capsule trim angle of attack, capsule lift coefficient at trim, and capsule drag at zero lift. In general, whether the jet was off or on, the effect of positioning the capsule close to the fuselage (configuration 2) was a decrease in the capsule trim angle of attack, lift at trim, and drag at zero lift. At a given angle of attack, the results in Figs. 4 and 5 show that positioning the capsule near the fuselage increased the lift and produced a negative increment of pitching moment. The magnitude of these effects caused by the proximity of the fuselage to the capsule was found to decrease with both Mach number and separation distance until at the largest separation distance (configuration 7) little or no influence of either Mach number or distance is present in the results.

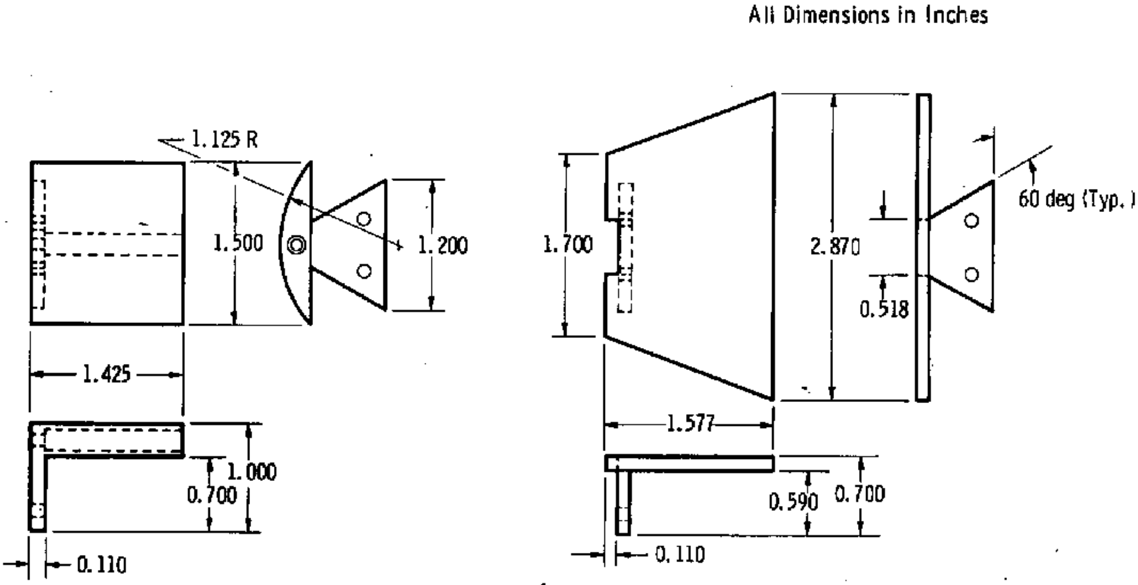
REFERENCES

1. Leroy M. Jenke, Jerry H. Jones, and A. W. Myers. "Force Tests on a Separable-Nose Crew Escape Capsule with Cold Flow Rocket Jet Simulation at Mach Numbers 1.5 through 6." AEDC-TR-66-74, April 1966.

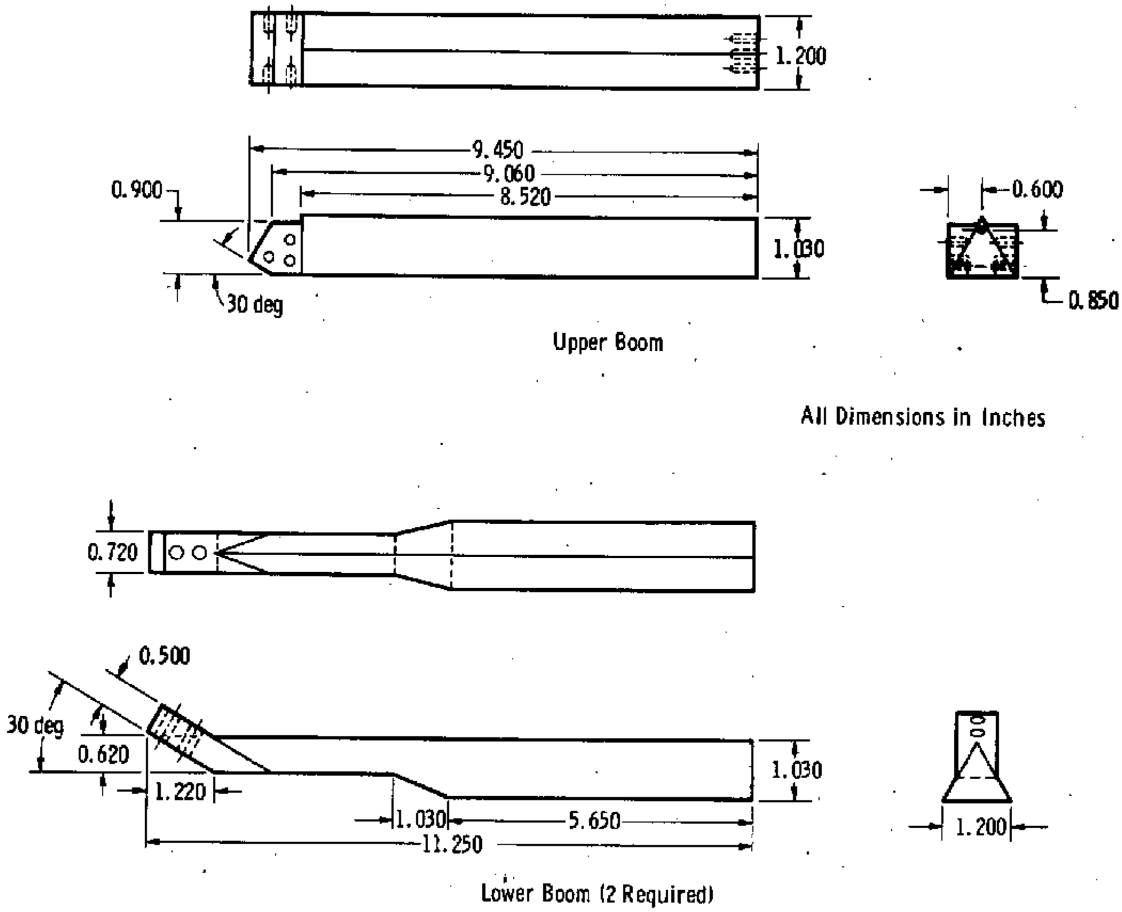
2. Test Facilities Handbook (5th Edition). "von Kármán Gas Dynamics Facility, Vol. 4." Arnold Engineering Development Center, July 1963.



a. Capsule Details
Fig. 1 Model Details

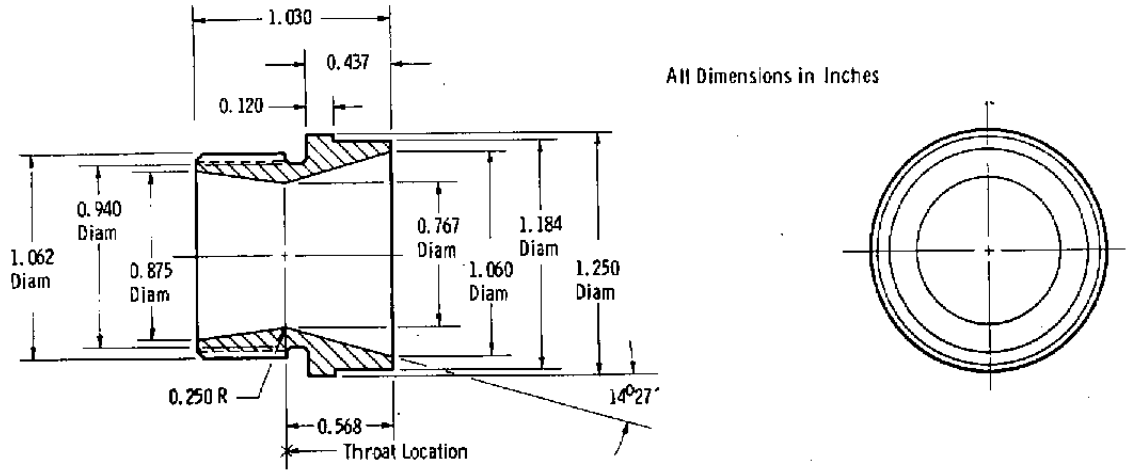


b. Trim Tab Details

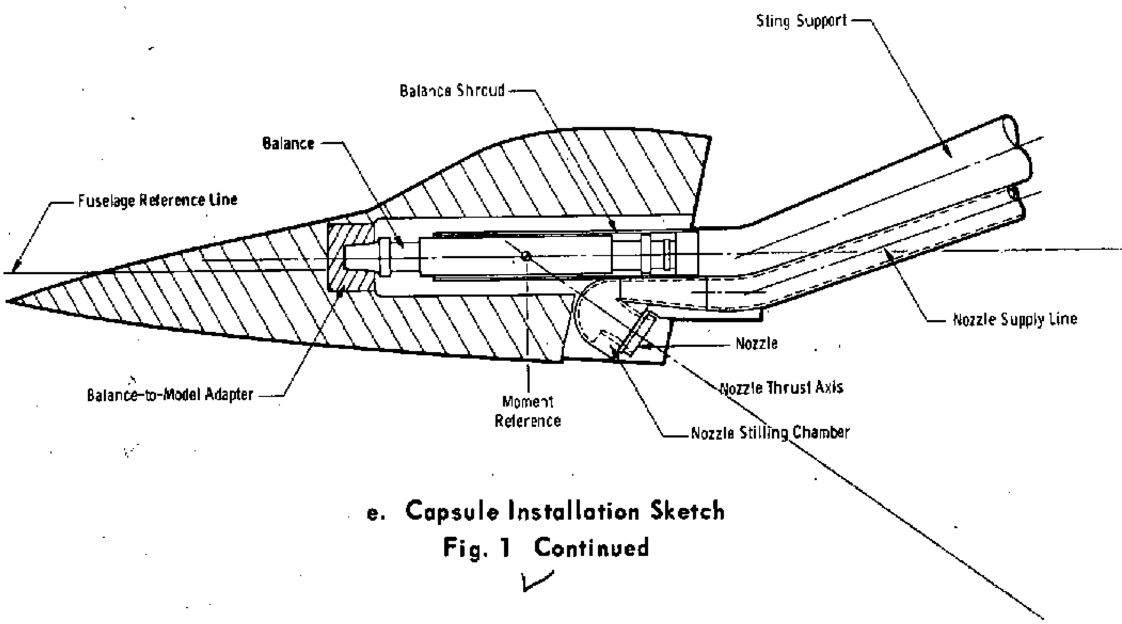


c. Trailing Boom Details

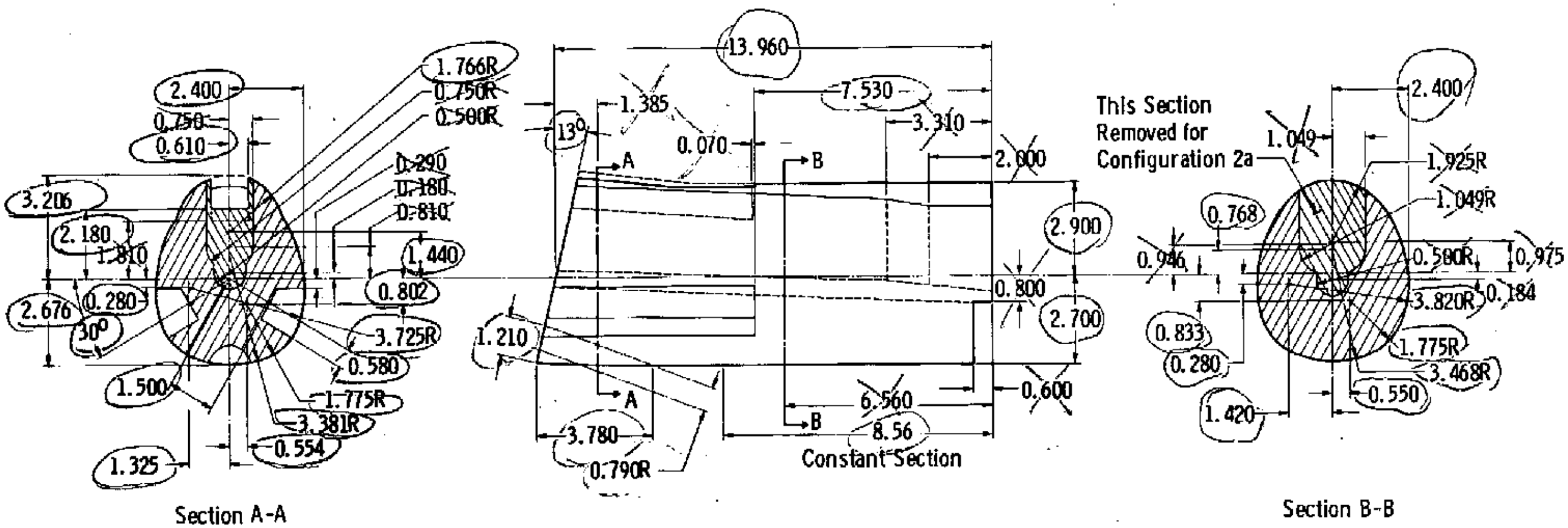
Fig. 1 Continued



d. Nozzle Details



e. Capsule Installation Sketch
Fig. 1 Continued

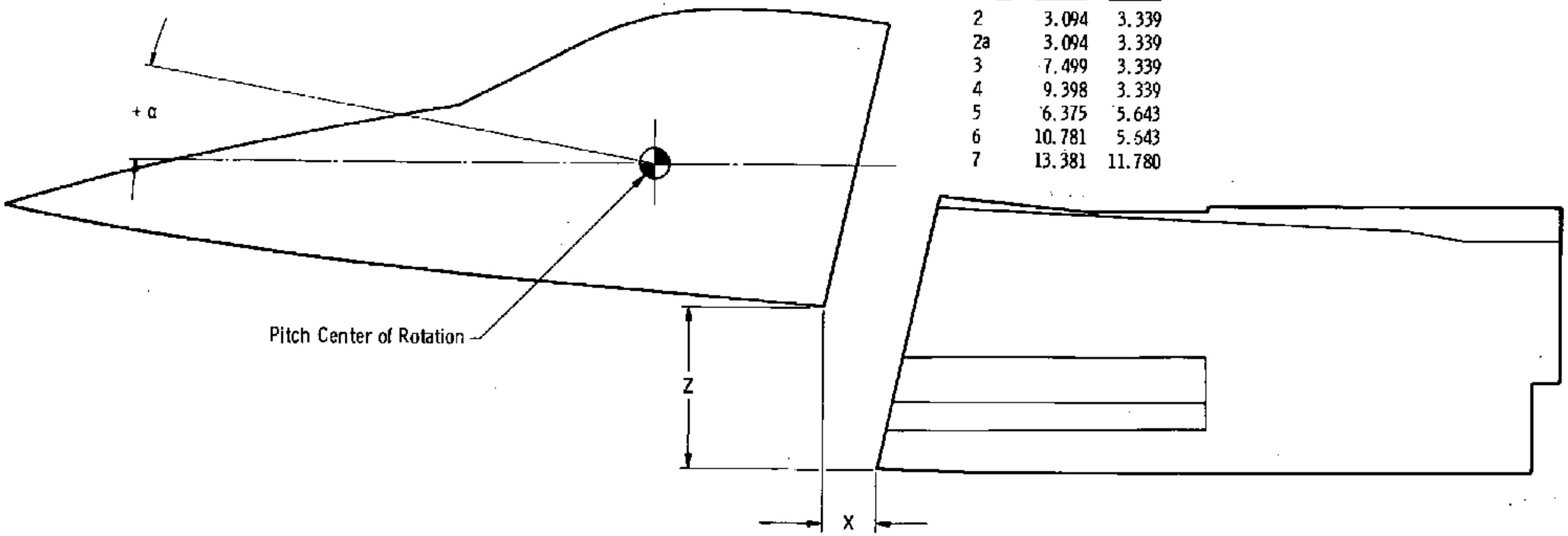


f. Fuselage Details

Fig. 1 Concluded

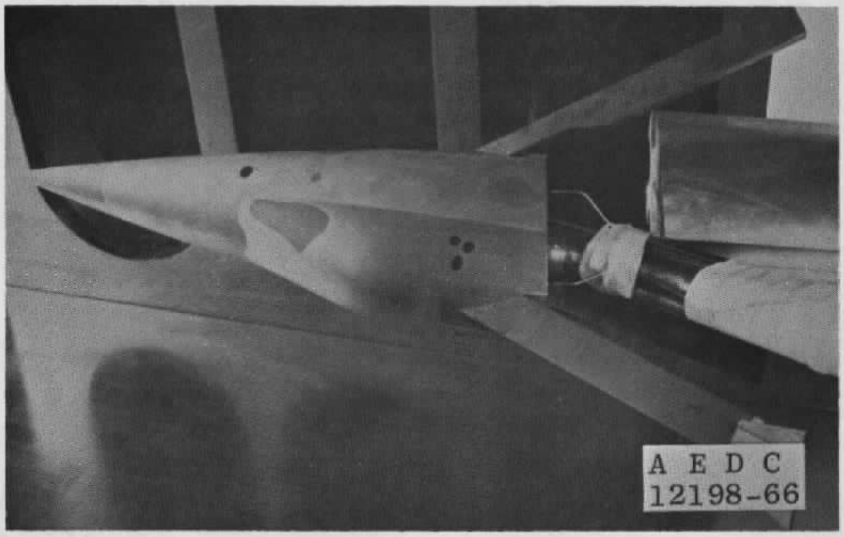
13,960
7.400
6.560

7.530
6.560
.970



Config.	X, in.	Z, in.
2	3.094	3.339
2a	3.094	3.339
3	7.499	3.339
4	9.398	3.339
5	6.375	5.643
6	10.781	5.543
7	13.381	11.780

Fig. 2 Configuration Details



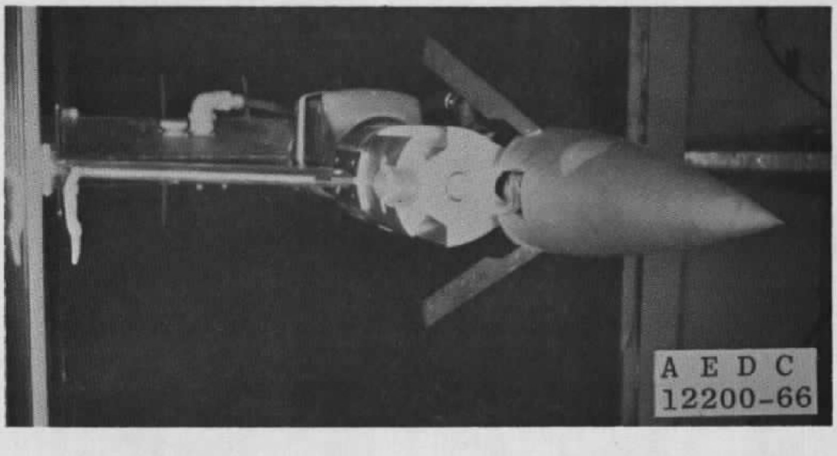
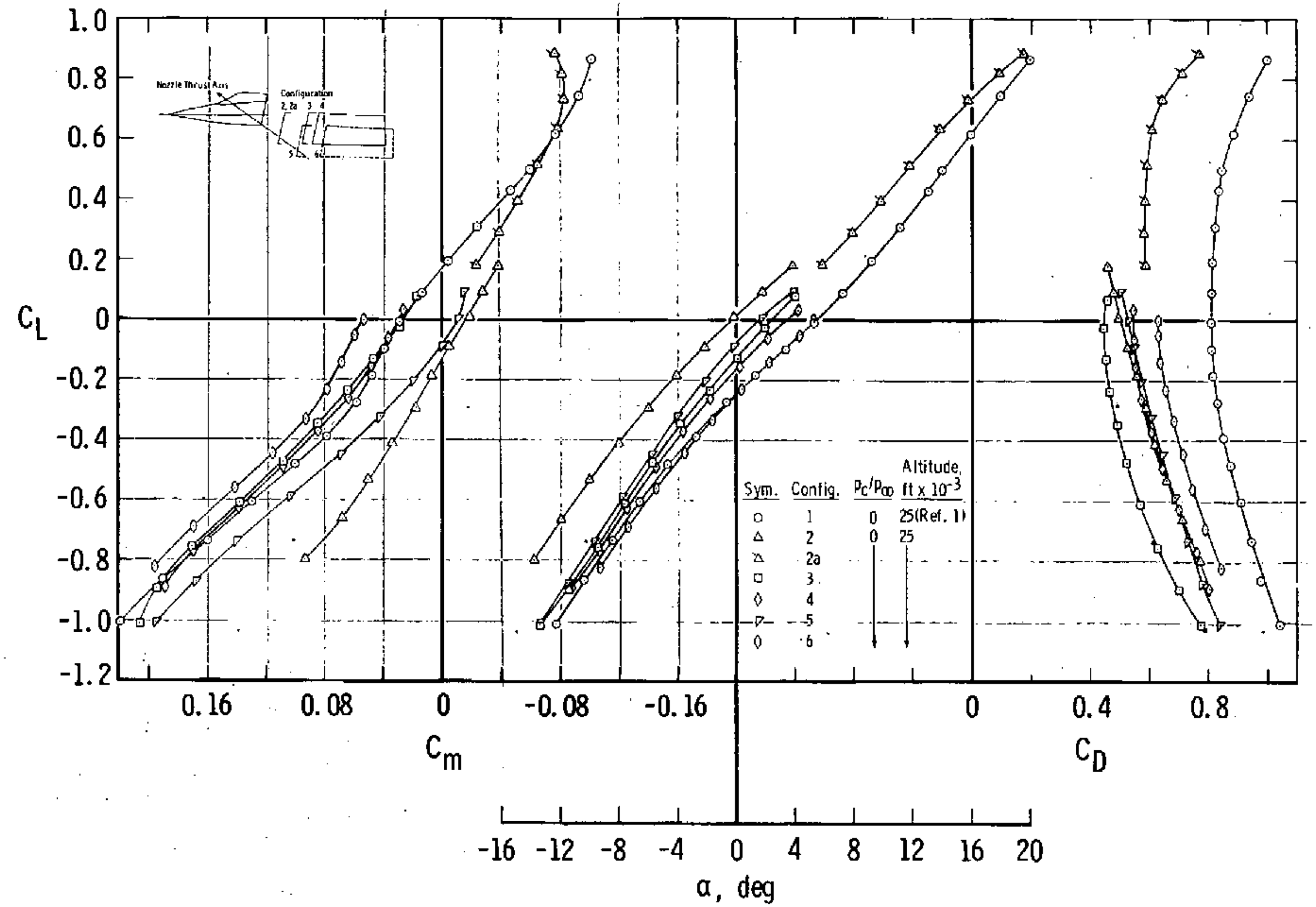
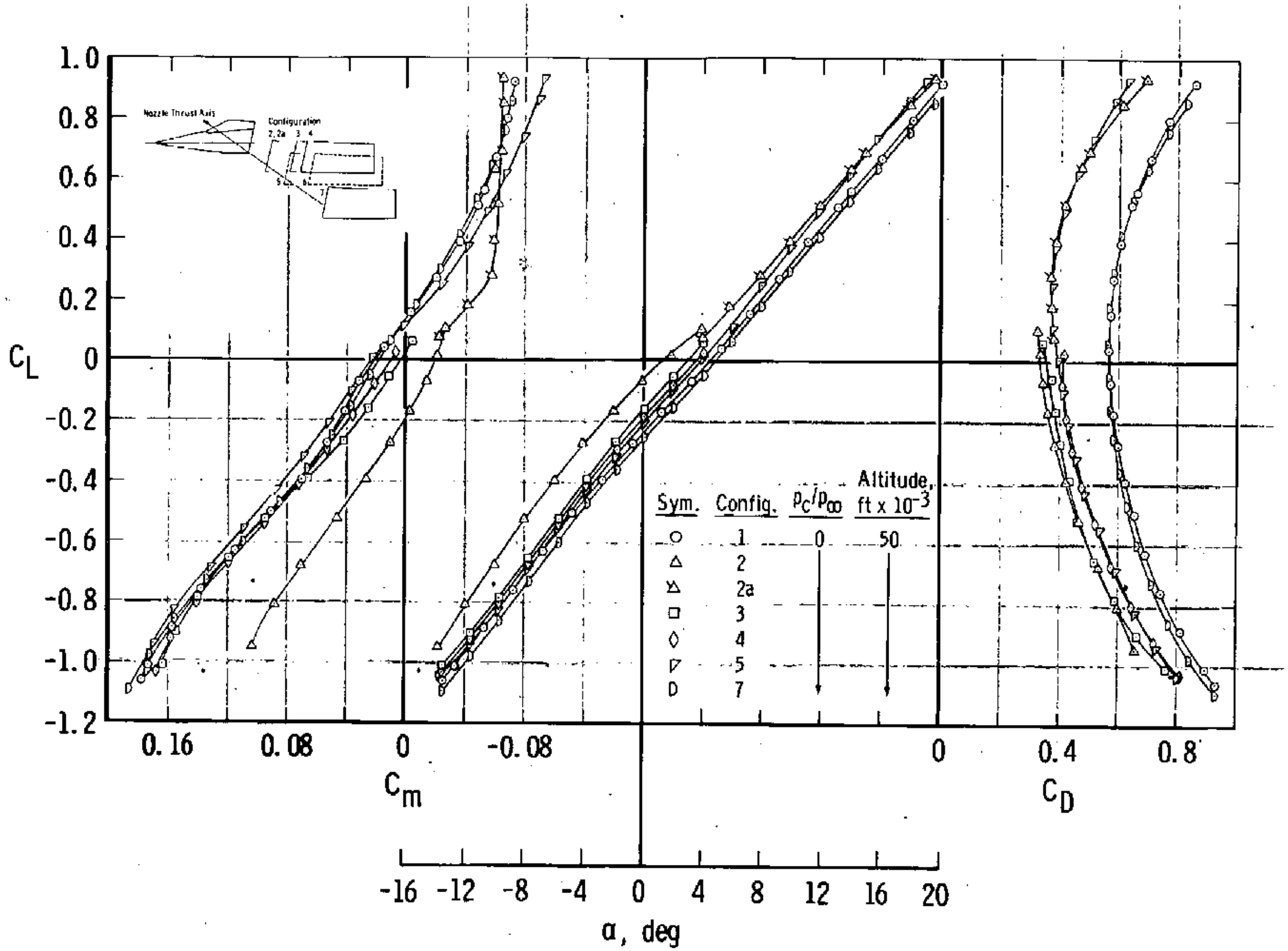


Fig. 3 Configuration 2 Installation Photographs



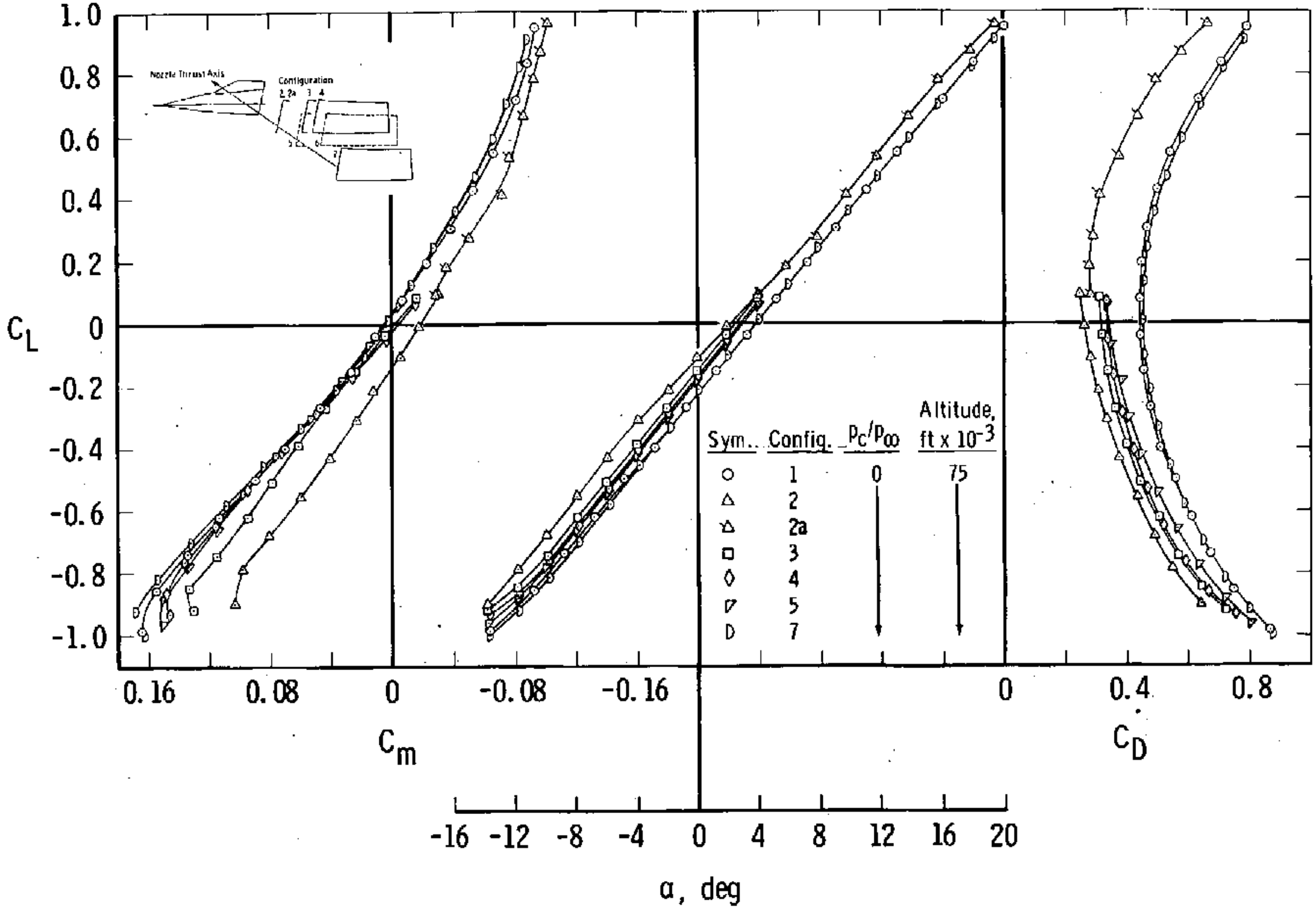
a. $M_\infty = 1.5$

Fig. 4 Longitudinal Stability and Drag Characteristics, Jet Off



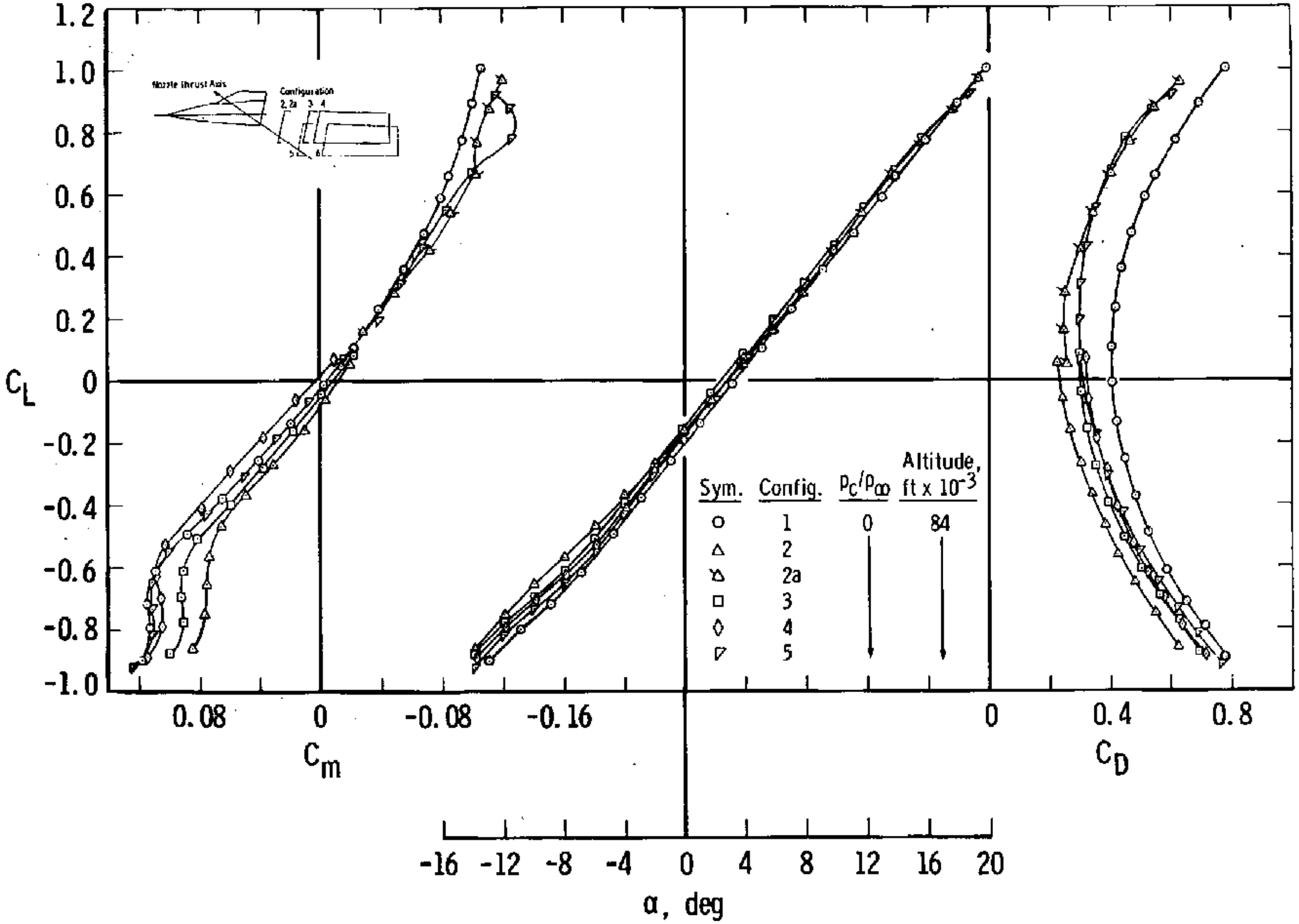
b. M_∞ = 2.5

Fig. 4 Continued



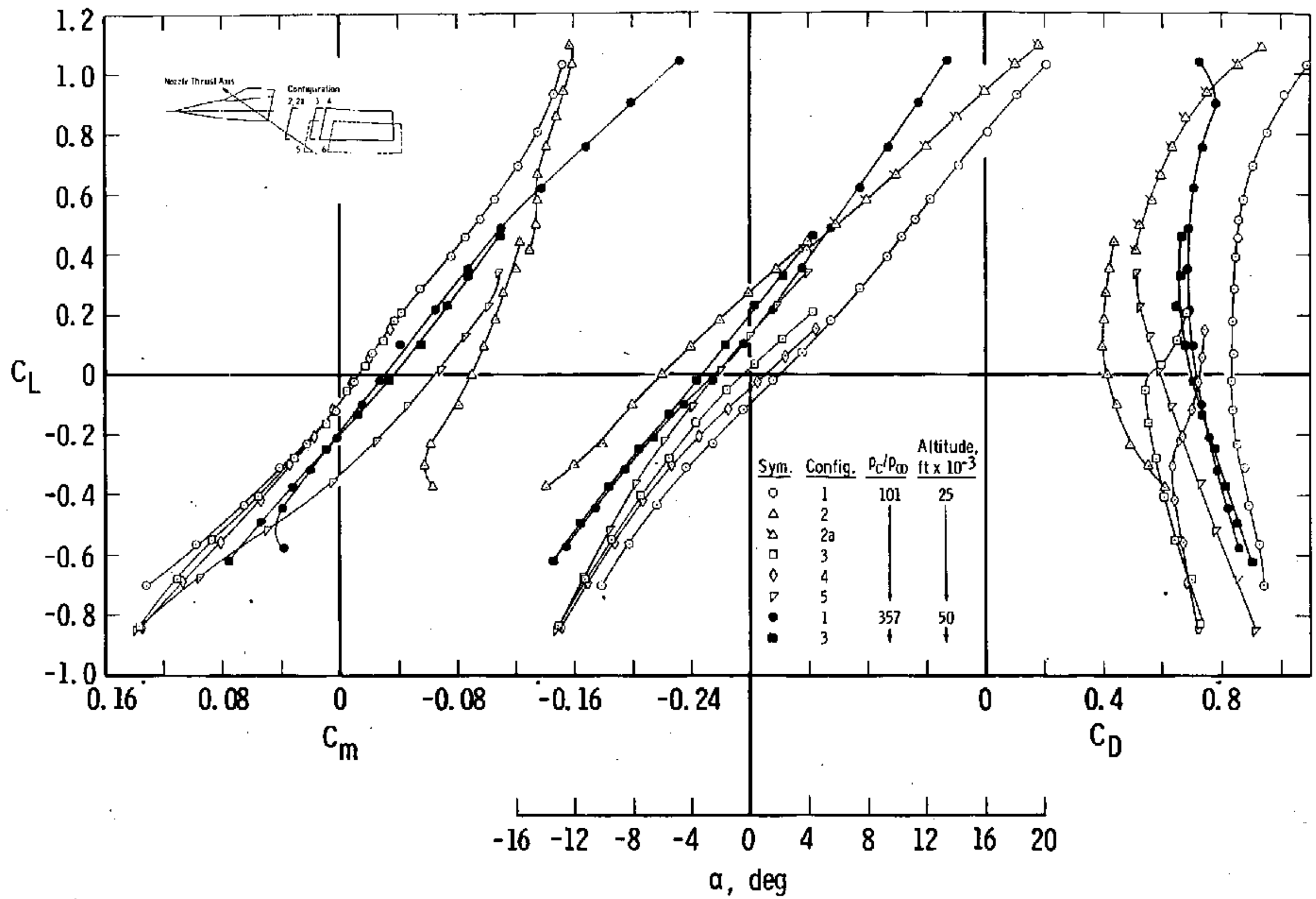
c. $M_\infty = 3.5$

Fig. 4 Continued



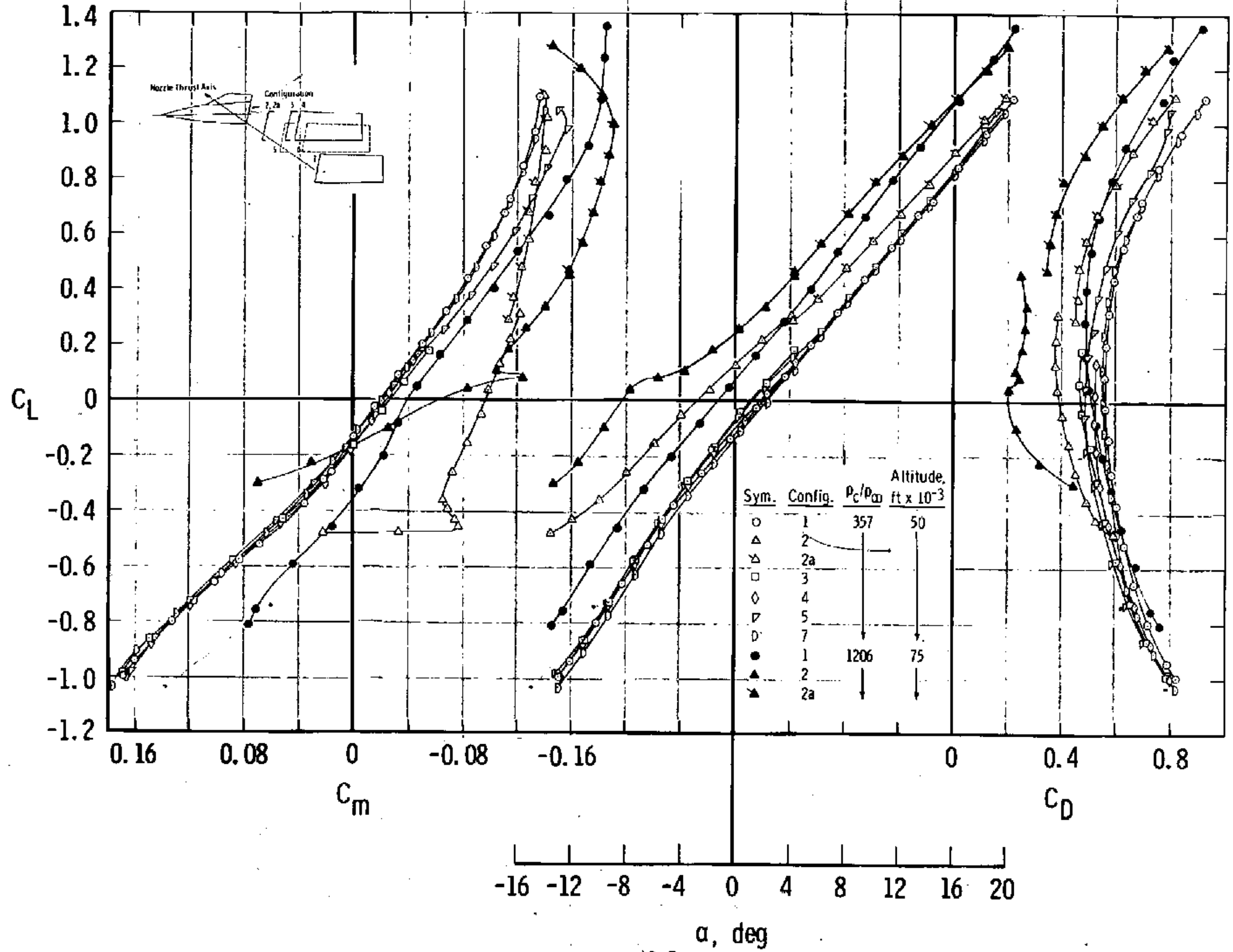
d. $M_\infty = 4.5$

Fig. 4 Concluded



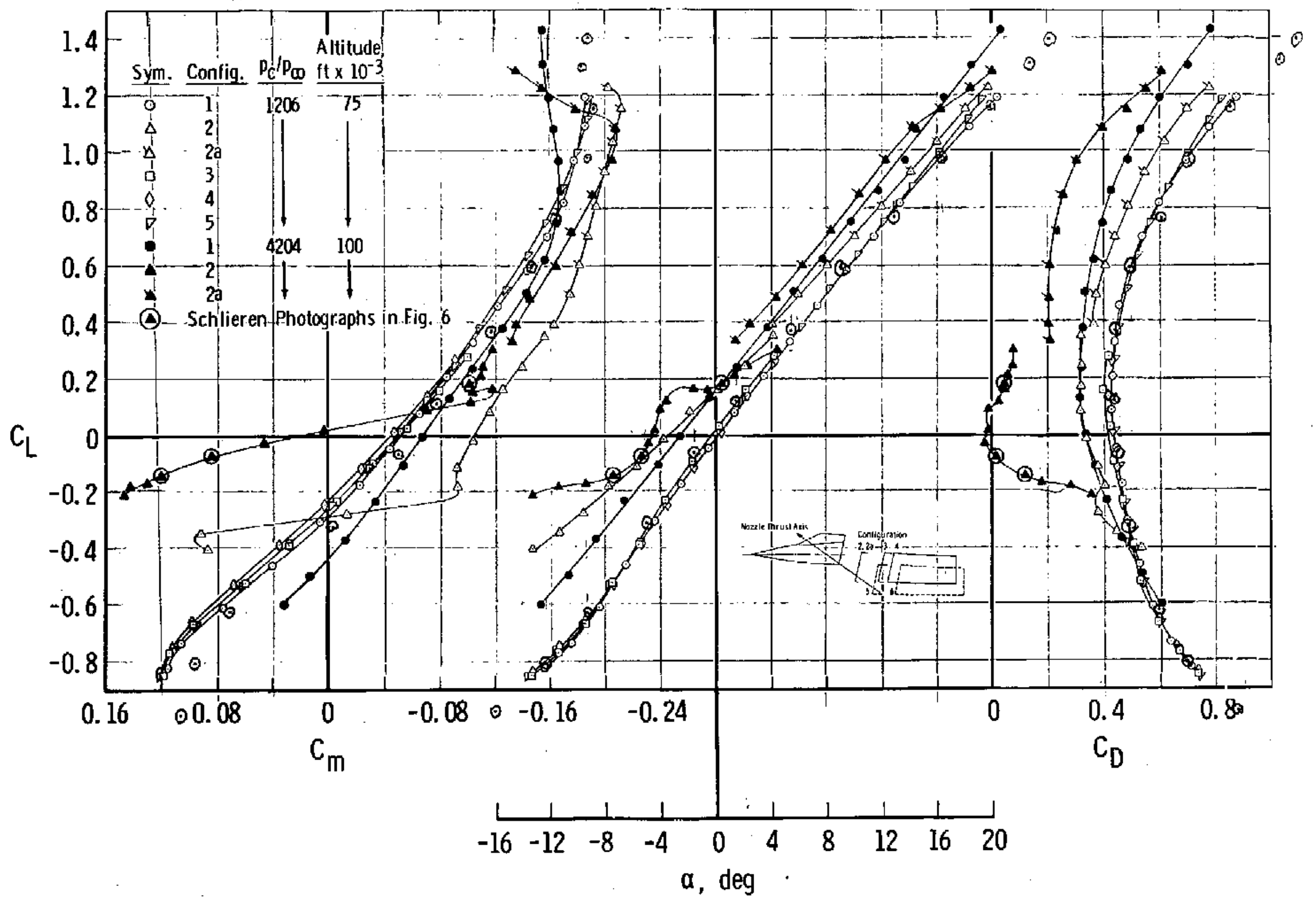
a. $M_\infty = 1.5$

Fig. 5 Longitudinal Stability and Drag Characteristics, Jet On



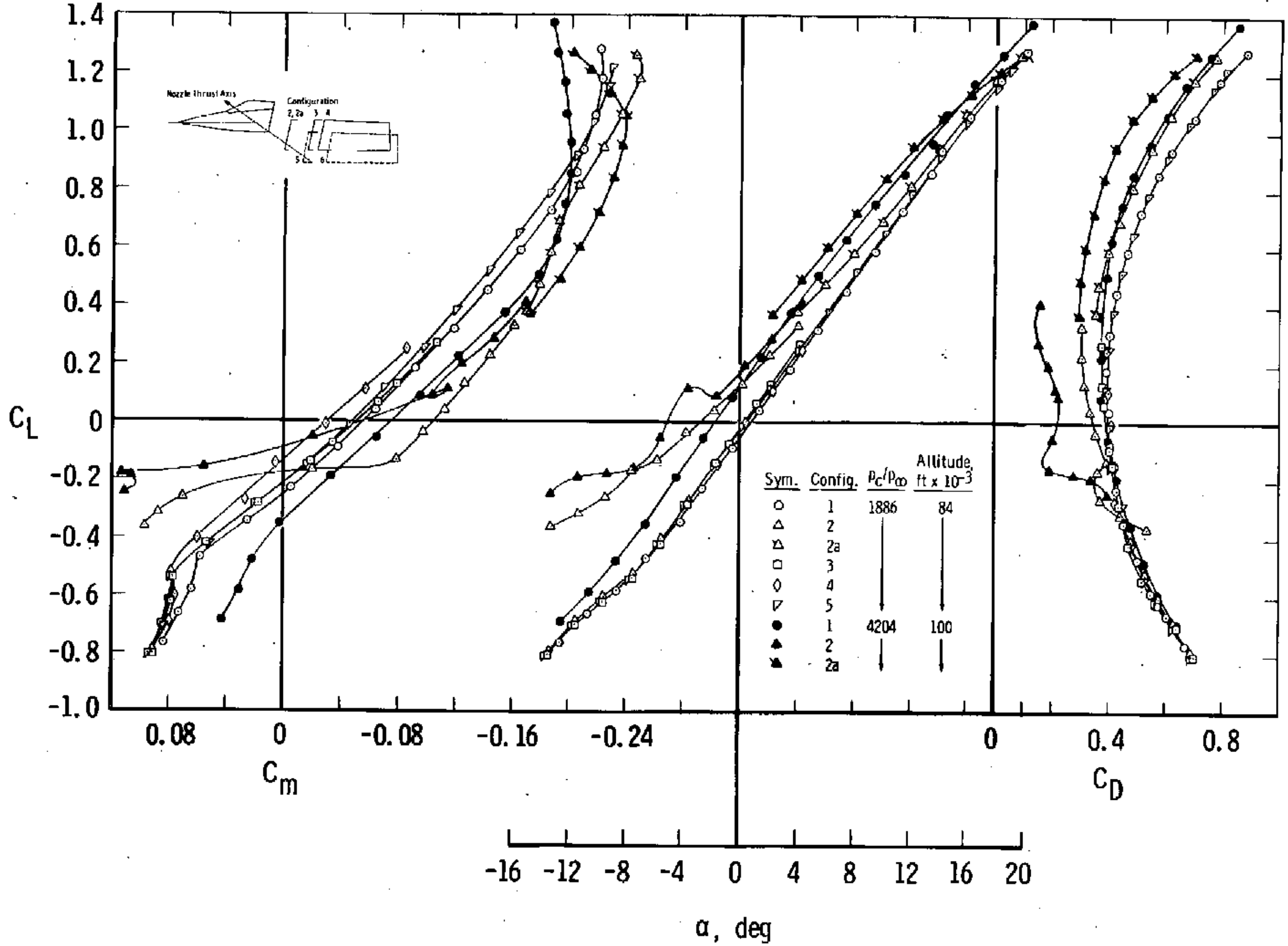
b. M_∞ = 2.5

Fig. 5 Continued



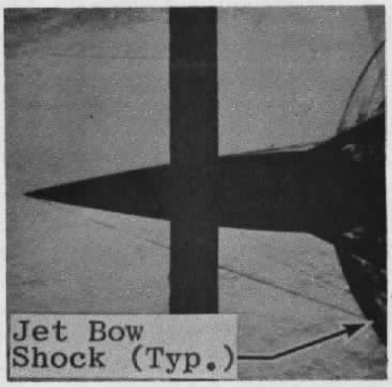
c. $M_\infty = 3.5$

Fig. 5 Continued

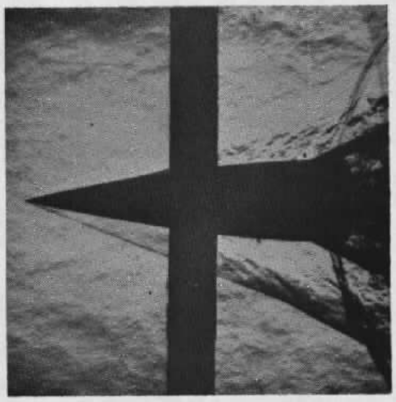


d. $M_\infty = 4.5$

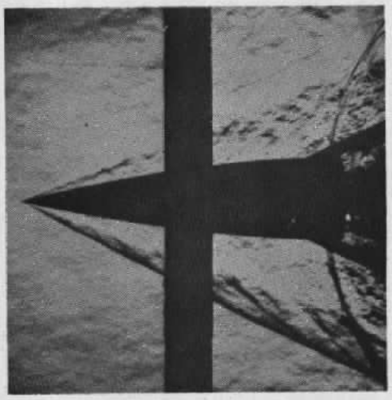
Fig. 5 Concluded



$\alpha = 0$



$\alpha = -6$ deg



$\alpha = -8$ deg

Fig. 6 Schlieren Photographs, Configuration 2, $M_\infty = 3.5$, Altitude = 100×10^3 ft, $p_c/p_\infty = 4204$

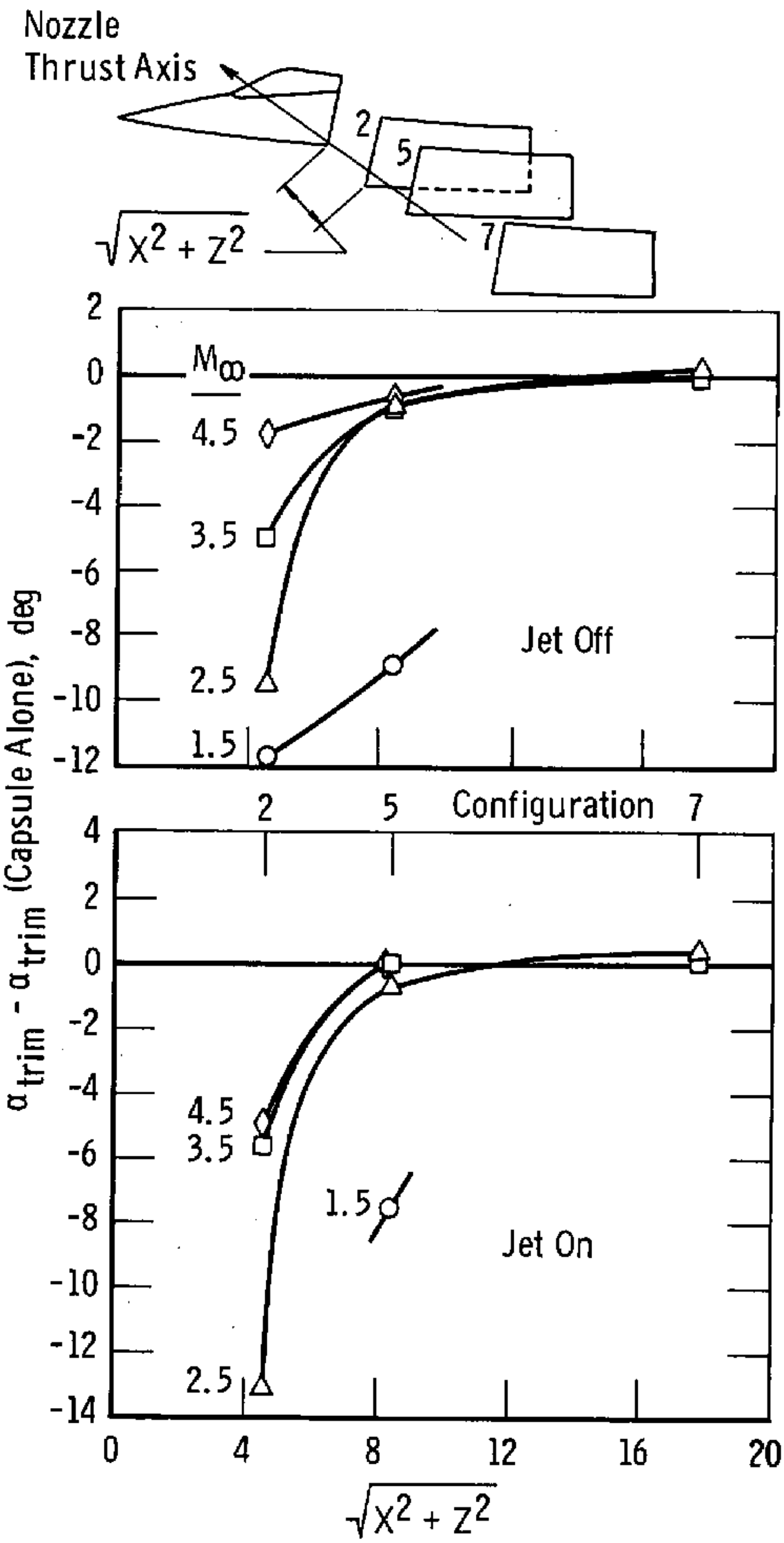


Fig. 7 Effect of Fuselage on Capsule Trim Angle of Attack

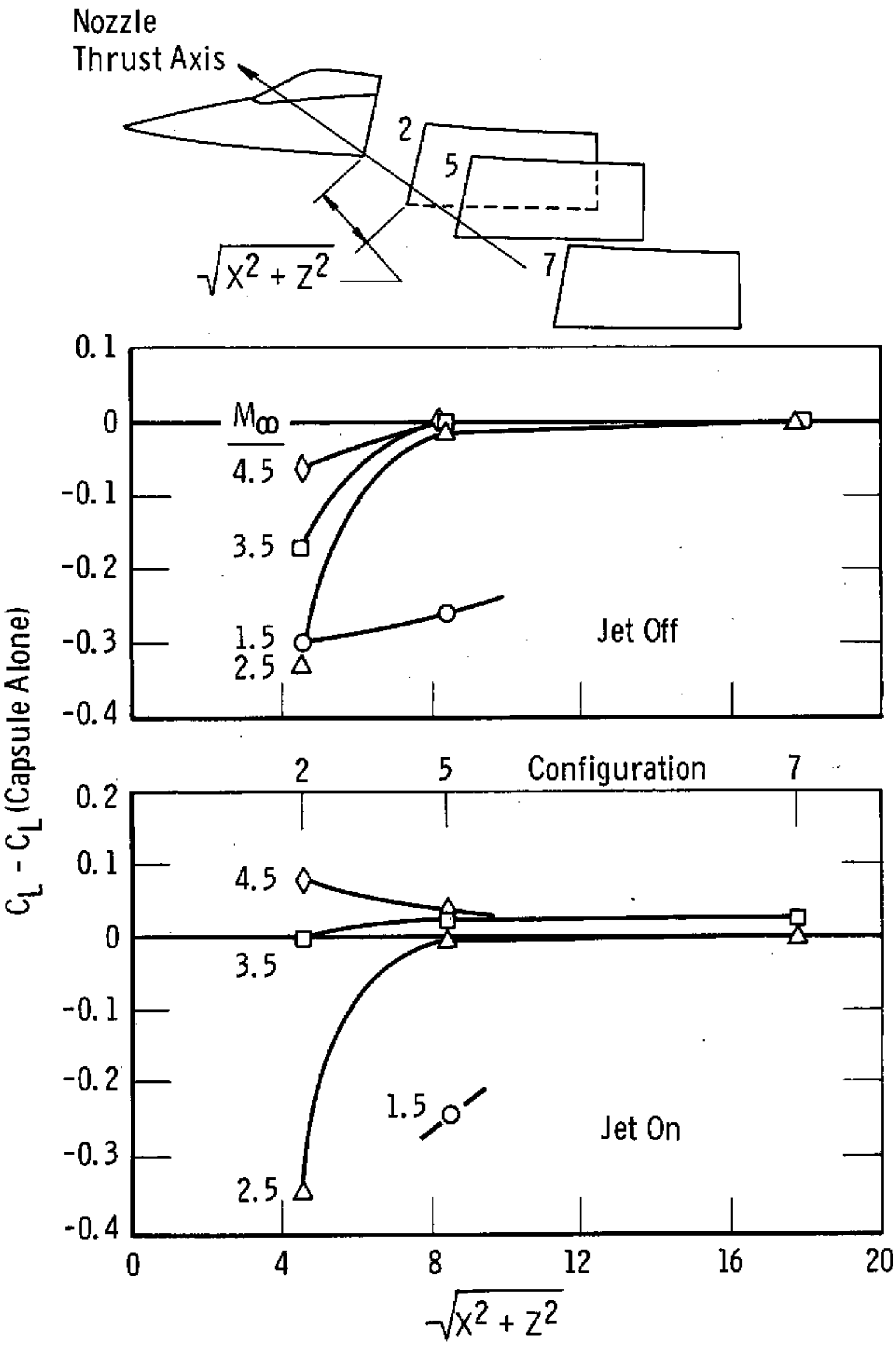


Fig. 8 Effect of Fuselage on Capsule Lift at Trim Angle of Attack

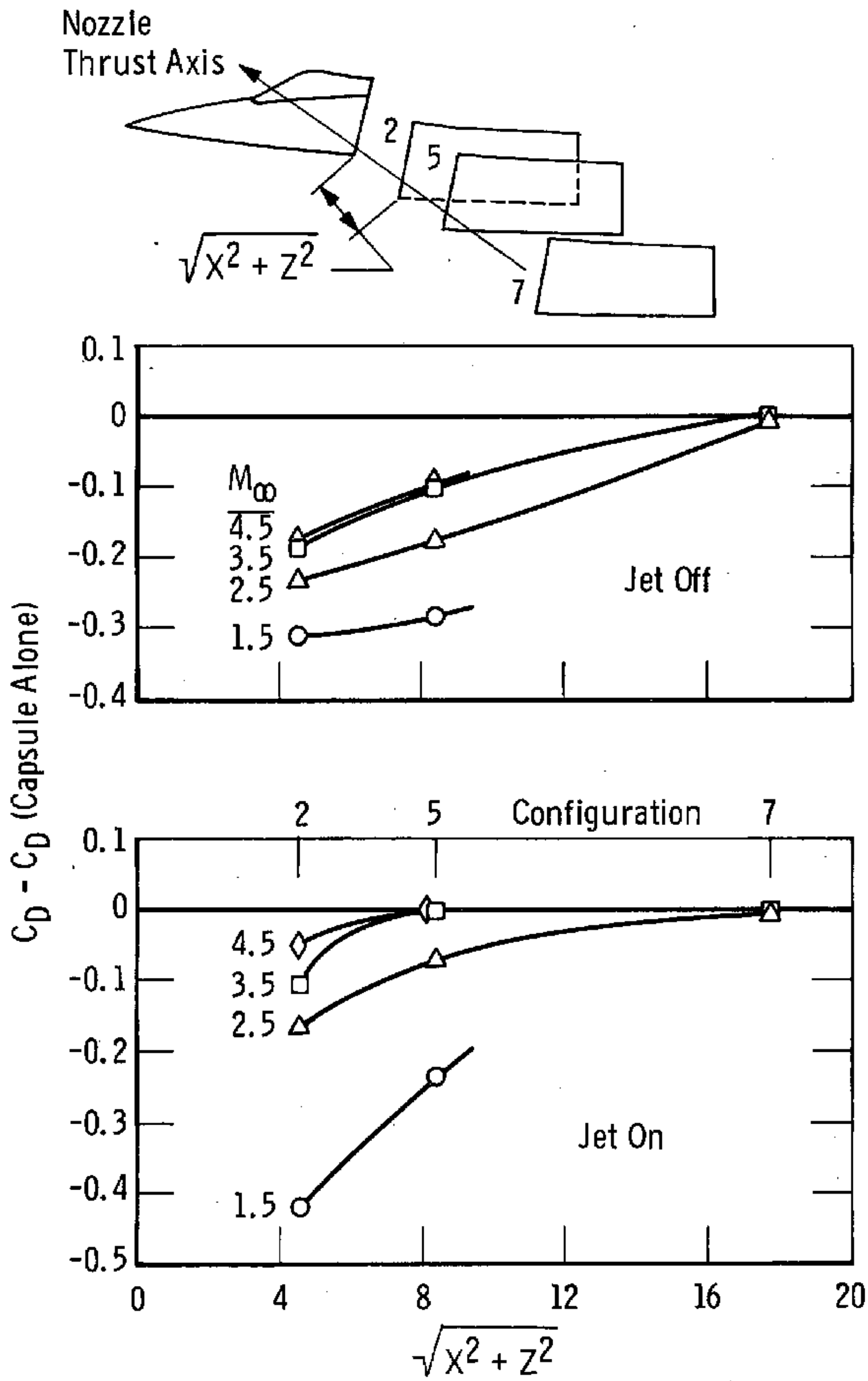


Fig. 9 Effect of Fuselage on Capsule Drag at Zero Lift

TABLE I
TEST CONDITIONS

Nominal M_∞	Calibrated M_∞	p_o, psia	T_o, °R	p_∞, psia	Re/in. x 10^{-6}	Altitude, ft x 10^{-3}	p_c/p_∞	Configurations Tested						
								2	2a	3	4	5	6	7
1.5	1.53	5.91	560	1.541	0.14	50	0	x	x	x	x	x	x	
1.5	1.52	19.45	560	5.146	0.47	25		x	x	x	x	x	x	
2.5	2.49	8.38	560	0.498	0.13	75		x	x	x	x	x	x	x
2.5	2.50	28.30	560	1.656	0.45	50		x	x	x	x	x		x
3.5	3.49	11.64	580	0.155	0.10	100		x	x	x	x	x	x	x
3.5	3.50	38.00	580	0.498	0.34	75		x	x	x	x	x	x	x
4.5	4.53	46.60	590	0.155	0.24	100		x	x	x	x	x	x	x
4.5	4.54	100.00	590	0.329	0.52	84	0	x	x	x	x	x	x	x
1.5	1.53	5.91	560	1.541	0.14	50	357			x	x		x	
1.5	1.52	19.45	560	5.146	0.47	25	101	x	x	x	x	x		
2.5	2.49	8.38	560	0.498	0.13	75	1206	x	x	x	x	x	x	x
2.5	2.50	28.30	560	1.656	0.45	50	357	x	x	x	x	x		x
3.5	3.49	11.64	580	0.155	0.10	100	4204	x	x	x	x	x	x	x
3.5	3.50	38.00	580	0.498	0.34	75	1206	x	x	x	x	x	x	x
4.5	4.53	46.60	590	0.155	0.24	100	4204	x	x	x	x	x	x	x
4.5	4.54	100.00	590	0.329	0.52	84	1886	x	x	x	x	x	x	x

Notes: (1) See Fig. 2 for configuration details

(2)

Config.	α range, deg
2	-14 to 4
2a	0 to 20
3	-14 to 4
4	-14 to 4
5	-14 to 20
6	-14 to 4
7	-14 to 20

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13. ABSTRACT

Static force tests were conducted in the 40-in. supersonic tunnel of the von Kármán Gas Dynamics Facility on a separable-nose crew escape capsule in the presence of the forward section of the airplane fuselage. The separation rocket jet plume was simulated with cold air. Data were obtained at Mach numbers from 1.5 through 4.5 at capsule angles of attack from -14 to 20 deg. The fuselage section, relative to the capsule, was positioned at several locations aft of the capsule at zero angle of attack. Reynolds number, based on a model length of 18.1 in., ranged from 1.81×10^6 to 9.41×10^6. Selected results are presented showing the effects of the fuselage section on the static longitudinal stability and drag characteristics of the capsule.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
static force tests drag characteristics escape capsule F-104 supersonic flow						

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There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.